Preliminary Summary of Existing Biological Monitoring Data from Capisic Brook in Portland, ME

Above Capisic Pond,
April 2003

In Evergreen Cemetery,
April 2003

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EXECUTIVE SUMMARY

This executive summary briefly summarizes the contents of this report. More information on individual topics, findings, interpretations, and recommendations can be found in the sections given in parentheses at the end of each paragraph.

The Maine State Legislature in 1986 created the Water Classification Program so as to "restore and maintain the chemical, physical, and biological integrity of the State's waters and to preserve certain pristine State waters." This Program assigned classification standards to all surface waterbodies. In the case of rivers and streams, waters were classified as either Class AA, Class A, Class B, or Class C, and criteria for habitat, aquatic life, bacteria and dissolved oxygen were set to define those classifications. (see Introduction)

The Maine Department of Environmental Protection (MDEP) is charged with the task of safeguarding the health of Maine's rivers and streams. Within the MDEP, the Biological Monitoring Program has the responsibility to determine whether a waterbody meets the aquatic life standards of the water classification assigned to it under the Maine Water Classification Program. Since its beginnings in 1983, the Biological Monitoring Program has established almost 700 monitoring stations on approximately 240 rivers and streams throughout Maine. Samples of macroinvertebrates (small animals without a backbone, such as insects or worms) are collected and analyzed using standardized protocols and statistical models whose results indicate whether a waterbody meets its aquatic life criteria. If these criteria are not met, the MDEP has a mandate to improve the conditions in the waterbody. Following this mandate, the MDEP develops a stream-specific Total Maximum Daily Load (TMDL) plan which specifies maximum pollutant loads aimed at returning aquatic life to healthy conditions. (see Introduction)

During the first fifteen years of its existence the Biological Monitoring Program primarily monitored the water quality of mostly large rivers and streams impacted by point source discharges that can be attributed to a distinct entity; for example a wastewater treatment plant, pulp and paper mill, or heavy industry operation. More recently, the Program has expanded to include smaller streams impacted by nonpoint source (NPS) pollution that originates from diffuse sources as opposed to a distinct entity. Urban development in particular has been found to be responsible for contributing NPS pollution to streams, causing problems such as water pollution with nutrients and heavy metals, increases in water temperature, changes in water cycling and movement patterns, and erosion in and adjacent to a stream. In several cases, the Biological Monitoring Program has shown that such problems lead to a degradation in the resident macroinvertebrate community, causing a stream to violate its aquatic life standards. To better understand the effects urban development has on small streams, the MDEP has launched the Urban Streams Project to identify specific problems caused by NPS pollution and suggest ways of solving those problems. (see Introduction)

During the summer of 2003, the Urban Streams Project collected a wide variety of biological, chemical, and physical data on four streams in Maine. Capisic Brook in Portland was one of these four. Preliminary analysis of the results available to date from two sampling stations indicate that the following conditions exist in Capisic Brook:

<table>
<tr><th>Parameter</th><th>Upstream station
(Evergreen Cemetery)</th><th>Downstream station
(above Capisic Pond)</th></tr>
<tr><td>Macroinvertebrates</td><td>Not yet available</td><td rowspan="2">Degraded (animal diversity is low, most species present are tolerant to pollution)</td></tr>
<tr><td>Fish</td><td>Not studied</td></tr>
<tr><td>Water quality (e.g., dissolved oxygen levels, water temperature, nutrient levels)</td><td>Good</td><td>Impaired (i.e., at levels that may negatively affect biological communities)</td></tr>
<tr><td>Concentration of bacteria (of any origin)</td><td>Low</td><td>Elevated</td></tr>
<tr><td>Instream habitat quality</td><td>Good</td><td>Impaired</td></tr>
</table>

It is expected that as yet outstanding data will underscore the current interpretation of data already in hand, i.e., that water and habitat quality, and likely the macroinvertebrate community, at the upstream station are in a good condition, while those same parameters are all degraded at the downstream station.

Once data analysis is completed, the Urban Streams Project will develop a TMDL plan for Capisic Brook, which will address the problems encountered at the downstream station. It is unclear at this point, what specific pollutants or stressors the TMDL plan will address but it is likely that the following general recommendations will be considered during the TMDL development process (see Conclusions):

- Increase the dissolved oxygen level in the stream.
- Reduce the water temperature in the stream.
- Reduce the nutrient, bacteria and metal levels in the stream.
- Improve habitat quality in the stream and the area adjacent to the stream (the riparian zone).

It should be noted these recommended improvements in stream quality probably could be achieved by lowering the amount of stormwater runoff the stream receives, or by improving the runoff quality, and by eliminating combined sewer overflows. However, the recommendations made above are very general in nature, and development of the final TMDL plan will require the input of experts such as biologists, geologists, and engineers to tailor the contents of the plan to the specific conditions encountered in Capisic Brook. Implementation of the TMDL plan should lead to a considerable improvement in the health of the stream and its resident aquatic communities over the next few years. Future monitoring is advisable to determine whether the TMDL plan achieved its goal of restoring aquatic life to Class C standards at the downstream station in Capisic Brook, or whether additional actions are required. (see Conclusions)

INTRODUCTION

Rivers and Streams in Maine

The Federal Clean Water Act of 1972 requires that states protect and maintain the chemical, physical and biological integrity of the nation's waters. In pursuit of this directive, the Maine State Legislature in 1986 created the Water Classification Program (Title 38 MRSA Art. 4-A) so as to "restore and maintain the chemical, physical, and biological integrity of the State's waters and to preserve certain pristine State waters." Recognizing that it was unrealistic to assign the same environmental goals to all of the State's fresh surface waters, the Legislature adopted the following four classes of fresh surface waters, excluding great ponds:

- Class AA Waters. Class AA is the highest classification and is applied to waters that are outstanding natural resources which should be preserved because of the ecological, social, scenic or recreational importance.
- Class A Waters. Class A is the second highest classification.
- Class B Waters. Class B is the third highest classification.
- Class C Waters. Class C is the fourth highest classification and establishes the State's minimum environmental goals.

The classification system is based on water quality standards that designate uses for each of the four water classes. For example, "Class C waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life."[1] To ensure that water quality was sufficient to protect the designated uses, the Legislature established narrative criteria (for habitat and aquatic life) as well as numeric criteria (for bacteria and dissolved oxygen). For example, "The dissolved oxygen (DO) content of Class C waters may be not less than 5 parts per million (ppm) or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes must be maintained. Between May 15th and September 30th, the number of *Escherichia coli* bacteria of human origin in these waters may not exceed a geometric mean of 142 per 100 milliliters or an instantaneous level of 949 per 100 milliliters. The board shall promulgate rules governing the procedure for designation of spawning areas. Those rules must include provision for periodic review of designated spawning areas and consultation with affected persons prior to designation of a stretch of water as a spawning area. Discharges to Class C waters may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community."[1, 2]

The task of determining whether a river or stream meets its assigned water quality class rests with the Maine Department of Environmental Protection (MDEP). Depending on

[1] Class C was chosen as an example here because Capisic Brook is classified as a Class C stream.
[2] The abbreviations for dissolved oxygen (DO) and parts per million (ppm) are not used in the original text.

the situation, various MDEP programs may be asked to assess water quality, and determine whether water quality standards are met. In the case of aquatic life criteria, assessments are performed by the MDEP Biological Monitoring Program. The program began evaluating biological communities in rivers and streams in 1983, and by late summer 2003 had established close to 700 monitoring stations on approximately 240 rivers and streams throughout Maine. Biological data are collected in accordance with a standardized sampling protocol developed by the program, and are analyzed using statistical models. These models estimate the association of a biological sample to the four water quality classes defined by Maine's Water Classification Program (see above), thus indicating attainment or non-attainment of aquatic life standards. Findings of the Biological Monitoring Program are used to document existing conditions, identify problems, set water management goals, assess the progress of water resource management measures, and trigger needed remedial actions. More information on the Biological Monitoring Program can be found in Davies et al. 1999, MDEP BLWQ 2002 (see the References section at the end of this report), or on the following website: *www.state.me.us/dep/blwq/docmonitoring/biomonitoring*.

Biological Assessments of Impacts of Urbanization on Streams

During the first fifteen years of its existence, the Biological Monitoring Program primarily monitored the water quality of rivers and streams impacted by point source discharges, which predominantly affected larger waterbodies such as the Penobscot and Piscataquis rivers. Point source discharges are those that can be attributed to a distinct entity such as a wastewater treatment plant, pulp and paper mill, or heavy industry operation. More recently, biological monitoring has expanded to include streams impacted by nonpoint source (NPS) pollution that has led to a focus on smaller waterbodies or waterbodies where it is presumed that nonpoint sources are the major cause of water quality impairment.

Nonpoint source pollution is defined as pollution that originates from a number of diffuse sources as opposed to a distinct entity. Land use activities related to development (urbanization), agriculture, forestry activities, and transportation, as well as deposition on land of particles from the atmosphere all may lead to NPS pollution. This type of pollution affects waterbodies in two ways: first, changes in land use patterns alter the local watershed hydrology, the water cycling and movement patterns within the specific land area that drains water into a body of water; and second, runoff from the land carries increased pollutant loads into waterbodies, leading to habitat alterations and to changes in the system of interactions between living organisms and the nonliving environment (i.e., ecosystem changes).

The specific effects of land use activities depend on the types of land uses occurring in a watershed and their extent. Development associated with urbanization is the greatest threat to water quality since it entails the most dramatic changes and is rapidly expanding while other types of land uses tend to be stable or declining. It is also typically an irreversible type of land use change. Urbanization leads to substantial increases in impervious surfaces that do not allow water to soak into the ground, such as roads, rooftops and parking lots. As a result, the amount of stormwater that runs off into a waterbody rather than soaking into the ground (the stormwater runoff) increases, usually in direct proportion to the extent of watershed imperviousness. At the same time, reduced water infiltration into the ground causes lower baseflows (the amount of water in a stream that comes from groundwater discharge), sometimes causing streams to entirely dry up during the warmest part of the year. The combination of increased stormwater runoff and reduced baseflow means that, in contrast to waterbodies in non-urbanized watersheds, waterbodies in urbanized watersheds tend to receive a proportionally greater amount of their flow from surface runoff than from groundwater. Elevated levels of surface, especially stormwater, runoff cause more frequent and extreme high flow events which can cause severe bank erosion and channel scouring to the extent that the morphology (structure) of a stream will change. Typically, a stream will become wider and shallower, and sediment loading from bank erosion and watershed sources increases. In addition to altering stream flow patterns, stormwater runoff can increase the concentration of water pollutants such as toxics like gas or oil from gas stations or garages, nutrients from fertilizers, bacteria from pet waste, or sediment from construction sites. Finally, runoff from hot pavements can increase stream water temperature to levels that are unhealthy for biological communities, an effect that can be exacerbated by the absence of shade-providing vegetation in the riparian zone adjacent to the stream.

The combined effects of land use changes within a watershed, particularly when associated with urbanization, can severely stress aquatic resources such as fish and macroinvertebrates (small animals that lack a backbone, for example insects or worms), leading to predictable changes in the instream biological community. Biological communities thus function as useful indicators of the health of a waterbody and can be monitored to determine the effects of human influences upon freshwater resources.

MDEP Urban Streams Project

The MDEP Biological Monitoring Program has identified a number of rivers and streams in Maine which are impacted by various types of land use changes. The Clean Water Act requires states to improve the quality of impacted streams by developing Total Maximum Daily Load (TMDL) plans aimed at removing or alleviating stressors that have been identified as causing an impairment. While traditional TMDL plans deal with pollutants that typically originate from point sources of pollution, pollutants originating from nonpoint sources are harder to deal with because of the absence of a distinct “polluter”. To address this problem, the Biological Monitoring Program in early 2003 launched a pilot project to develop TMDLs dealing with NPS pollutants and the impairments they create. Under the Urban Streams NPS TMDL Project, or Urban Streams Project, a large amount of biological, physical, and chemical data has been collected in four urban streams, including Capisic Brook in Portland. Once data collection and analysis have been completed, a comprehensive report summarizing the findings will be distributed to a group of experts (biologists, geologists, engineers) who will identify the particular stressors causing the impairments detected in the four study streams. Following the stressor identification process (US EPA 2000), recommendations for Best Management Practices (a practice or combination of practices that are deemed the most effective, practical means of reducing the amount of NPS pollution to a level compatible with water quality goals) and remedial actions aimed at removing or alleviating the stressors will be developed. These recommendations will aid in the development of stream-specific TMDL plans whose implementation will hopefully allow the streams to recover.

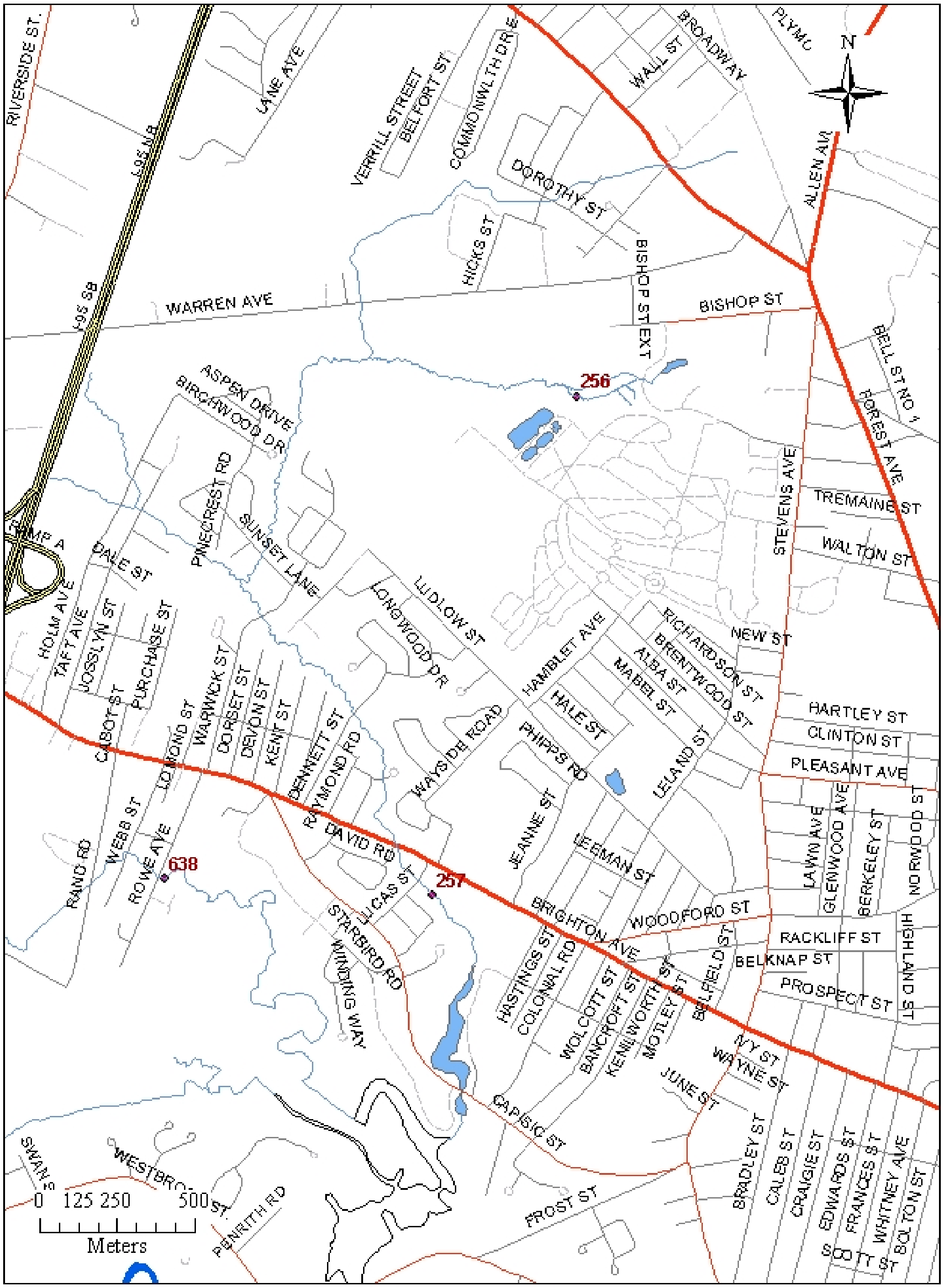
Capisic Brook in Portland

Capisic Brook (Fig. 1), one of the four streams in the Urban Streams Project, is located in Portland (southern Maine), and is of moderate length (~2.5 miles) and watershed size (~1,500 acres). The stream consists of several branches, with headwaters located east of Forest Avenue near the intersection with Allen Avenue (Rt. 100), in Evergreen Cemetery (near biomonitoring station 256), and just east of I-95 near the intersection with Warren Avenue. Except for the section within Evergreen Cemetery, most the of the stream flows through a watershed with a high percentage of impervious surfaces (~28 %). As a result, the majority of Capisic Brook is affected by a variety of urban stressors typically associated with residential and commercial development and an extensive road system.

Data collected by the MDEP Biological Monitoring Program in 1996 and 1999 at two stations indicated that the upstream station in Evergreen Cemetery had a macroinvertebrate community that met the minimum aquatic life criteria of Class C. Conversely, data collected in the same years at the downstream station (~300 yards upstream from Capisic Pond, just below the Lucas Street bridge) showed a consistent violation of the Class C aquatic life standards (see Previous Study, below) thus requiring a TMDL assessment. Existing data also suggest that at the downstream station problems sometimes occur with a number of water quality parameters (e.g., dissolved oxygen, some nutrients). These impairments likely can be attributed to the effects of extensive impervious surfaces with their associated usages, such as retail and industrial complexes, roads, parking lots, etc.

This report presents the data that are available and have been analyzed to date (January 2004), and integrates the information into the context of stream health. A full scientific report covering all the findings of the Urban Streams Project in all four study streams will likely be completed in late spring 2004. Recommendations for improvements will be made in the summer of 2004, and stream-specific TMDL plans will be developed between the fall of 2004 and spring of 2005. It is expected that the MDEP Biological Monitoring Program will reassess the macroinvertebrate community in Capisic Brook within the next 2-3 years; further sampling events may occur in future years depending on developments in the watershed, funding availability, and program needs.

Fig. 1. Capisic Brook, Portland



•Biomonitoring station

Note that Capisic Brook was traced from Citipix images, requiring some inferences where the stream was obscured or running underground.

PREVIOUS STUDY

The Biological Monitoring Program of the MDEP's Bureau of Land and Water Quality (BLWQ) collected macroinvertebrate data in 1996 and 1999 at the upstream and downstream stations (256 and 257, respectively; Fig. 1). Sample collection and processing methods are detailed in Davies and Tsomides (2002, App. i), and briefly described in Sampling Methods, Biological Monitoring, below. Macroinvertebrate samples were sorted at the MDEP laboratory and identified by either Lotic, Inc (Unity, ME; 1996) or Freshwater Benthic Services (Petosky, MI; 1999). The MDEP analyzed taxonomic data using a statistical model which assigned samples to one of three State of Maine water quality classes (A[3], B, or C) or to a Non-Attainment category. Analysis results were reported in the Maine DEP Surface Water Ambient Toxic Monitoring Reports (1999, 2001) and in Davies et. al (1999).

Model results indicated that in both years, macroinvertebrates at the upstream station met Class C aquatic life standards. The benthic community was low in pollution sensitive taxa from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies); instead, these sensitive organisms were replaced by relatively tolerant organisms in the order Diptera (flies). In both years, relatively few organisms were found (91 and 280), signifying the absence of nutrient enrichment. A good general indicator of the quality of a macroinvertebrate community is the percentage of non-insects in a sample, as non-insect taxa increase with decreasing water quality. The percentage of non-insects at the upstream station was low in both sampling years, namely 2.5 and 3.2 %. Water quality data collected at this station showed adequate dissolved oxygen concentrations (6.7 and 7.6 mg/L in 1996 and 1999, respectively), and low conductivity levels (80 and 44 μS/cm). For an explanation of dissolved oxygen and conductivity see Sampling Methods, Water Quality Monitoring, below. Continuous water temperature data collected between July 21 and August 20, 1999 (Fig. 2) were generally low (mean and maximum weekly temperature of <13º C and <16º C, respectively), i.e., favorable for healthy macroinvertebrate communities. Various water chemistry parameters were sampled in 1996, and results (Table 1) indicated that none of the parameters exceeded existing Water Quality Criteria.

The downstream station did not meet the minimum (i.e., Class C) aquatic life standards in either sampling year. The degraded macroinvertebrate communities in both sampling years were dominated by tolerant midge larvae and crustaceans (isopods). The number of organisms found was high in both years (1101 and 1327 in 1996 and 1999, respectively), signifying nutrient enrichment. The percentage of non-insects at this station was high, namely 28 and 34 %. These very tolerant non-insect organisms included worms, leeches, and isopods. Water quality data showed low dissolved oxygen concentrations (6.4 and 3.3 mg/L) and elevated conductivity levels (195 and 386 μS/cm). Continuous water temperature data collected between July 24 and August 20, 1999 (Fig. 2) were generally high, (mean and maximum weekly temperature of 19-22º C and 22-26º C, respectively), i.e., not favorable for healthy macroinvertebrate communities. Various water chemistry parameters were sampled in 1996, and results (Table 1) showed that Total Phosphorus and Copper exceeded Water Quality Criteria.

[3] For the purposes of the statistical model, water quality classes AA and A are combined.

Fig. 2. Continuous temperature in Capisic Brook in 1999

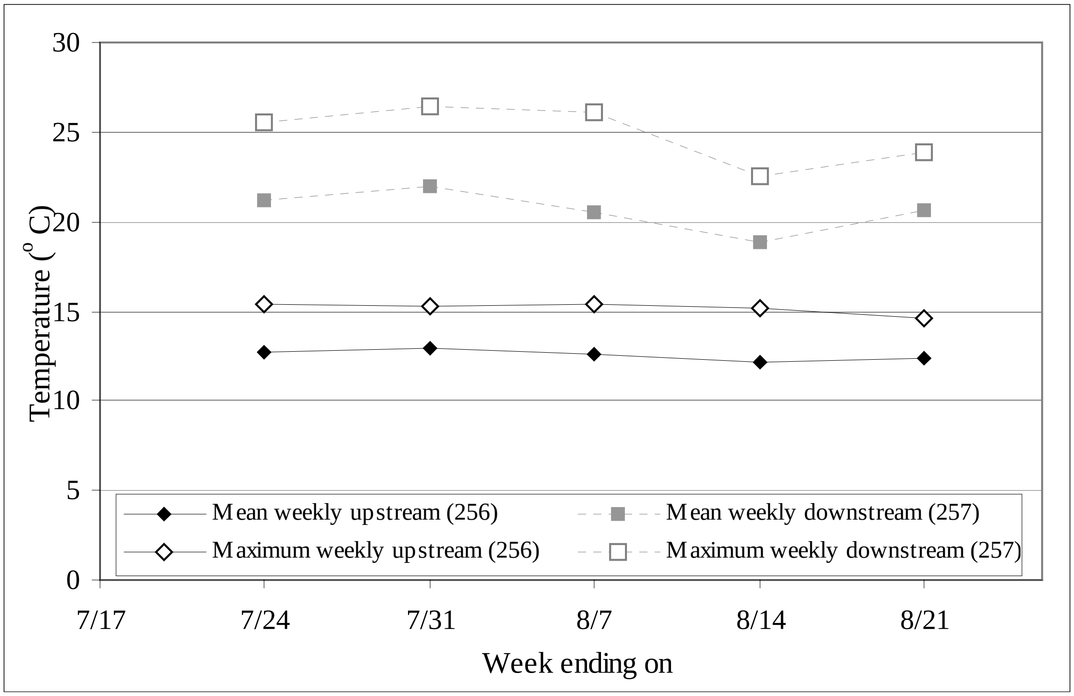


Table 1. Water chemistry data summer 1996

Parameters (unit)	Upstream (256)	Downstream (257)	Water Quality Criteria	
Total Phosphorus (mg/L)	0.012	0.140	0.031[1]	
Total Suspended Solids (mg/L)	5.5	2.5	NC	
Heavy metals			**CMC**[2]	**CCC**[2]
Cadmium (µg/L)	ND 0.5	ND 0.5	0.64	0.32
Copper (µg/L)	2.8	3.4	3.89	2.99
Iron (µg/L)	280	610	NC	1,000
Lead (µg/L)	< 2	< 2	10.52	0.41
Zinc (µg/L)	ND 4	ND 4	29.9	27.1
Manganese (µg/L)	13	75	NC	NC
Nickel (µg/L)	< 1	1.3	363.4	40.4

NC, No Criteria; ND, Not Detected, i.e., below stated detection limit of test. Highlighted fields indicate problem parameters.

[1] Criteria developed by EPA for Ecoregion XIV, which includes Capisic Brook.

[2] CMC, Gold Book Instream Acute Criteria; CCC, Gold Book Instream Chronic Criteria. CMC and CCC, which were developed by EPA, denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure.

SUMMER 2003 STUDY

SAMPLING METHODS

Biological Monitoring

1. The macroinvertebrate community was sampled once at the two stations (see Fig. 1) during a 4-week period in July and August 2003 using the protocol detailed in Davies and Tsomides (2002; App. i). Briefly, at each station, three replicate rock bags (Fig. 3) were deployed in the stream for ~28 days in riffle/runs. At the end of the colonization period, the bags were retrieved and the contents washed into a sieve bucket. These contents were transferred into labeled mason jars and preserved with 70% ethyl alcohol. Samples were sorted at the MDEP laboratory, and will be identified by a macroinvertebrate taxonomist. Biological data will be analyzed using a statistical model which assigns samples to State of Maine water quality classes (see Introduction, Maine's Rivers and Streams), or to a Non-Attainment category.

Fig. 3. Rockbag

2. The fish assemblage at the downstream station was investigated by staff of the MDEP Rivers section by electrofishing a 100 m long stretch, recording data on species composition and fish length. Details about the survey technique and equipment is given in App. ii. Fish diversity in Maine rivers and streams is generally fairly low compared to many other parts of the country, but a healthy stream the size of Capisic Brook could be expected to have around 6-7 different species, including American Eels, Brook Trout, Golden Shiner, Sticklebacks, Blacknose Dace, White Sucker, and Creek Chub. The diversity of fish actually encountered in a waterbody gives an indication of the health of the entire system.

Water Quality Monitoring

1. Standard water quality parameters (instantaneous dissolved oxygen, and specific conductance) were monitored at both stations 9-11 times during the period May through October using electronic field meters as detailed in App. iii. Dissolved oxygen (DO) concentrations are important for all aquatic fish and invertebrates as oxygen is required for respiration. Generally speaking, a concentration of 7 mg/L or above is considered favorable for healthy animal communities. Specific conductance, also often referred to as conductivity, is a measure of the ability of water to conduct an electrical current, which is related to the concentration of ions in the water. As many of these ions originate from human sources (e.g., fertilizers, road salts, metals abrading from car breaks and tires), conductivity can be used as an indicator of water pollution. In streams experiencing minimal human disturbance, conductivity is typically well below 100 μS/cm while urban streams in Maine have been found to have conductivity levels anywhere from 300 to 2500 μS/cm (MDEP Biological Monitoring Program, unpublished data).
2. Continuous dissolved oxygen (DO) was monitored at the downstream station from July 8-15, using a YSI data sonde, as explained in App. iv. Continuous monitoring of this

parameter can provide information on the minimum and maximum DO concentrations that occur in a stream. The daily (diurnal) range of DO concentrations can indicate whether problems may exist with an overabundance of algae that leads to high DO concentrations during the day and low concentrations at night. Generally speaking, a diurnal range of >2 mg/L DO is considered an indication of excess algal growth.

3. Temperature was monitored continuously (measurements taken every 30 min) from July 9 through September 24 at both stations using Optic Stowaway temperature loggers. Detailed information on the loggers and their use can be found in App. v. Summer temperature is an important instream parameter as many coldwater organisms can be severely stressed above 21º C.
4. Water chemistry parameters were sampled as shown in Table 2.

Table 2. Sampling schedule (parameters, stations, dates in 2003) for Capisic Brook.

Parameters	**Upstream (256)**	**Downstream (257)**
Nutrients		
Total Kjeldahl Nitrogen, Nitrate-Nitrite-N, Total Phosphorus	8/11, 8/25	7/15, 8/11, 8/25, 9/9
Ammonia	8/25	8/25
Ortho-phosphate	8/11	7/15, 8/11, 9/9
Dissolved Organic Carbon	8/11, 8/25	8/11, 8/25
Total Organic Carbon	8/11	8/11
Chlorophyll *a*	8/11	7/15, 8/11, 9/9
Total Suspended Solids	8/11, 8/25	7/15, 8/11, 8/25, 9/9
Bacteria (*E. coli*)	7/15, 8/11, 9/9	7/15, 8/11, 9/9
Metals		
Cadmium, Copper, Iron, Lead, Zinc	8/11	7/15, 8/11, 9/9
Chromium, Nickel	8/11	8/11
Chloride	8/11	8/11

Detailed information on the sampling and analysis protocols for these parameters can be found in Appendices vi and viii - xvii. The chain-of-custody form required by the analytical laboratory (State of Maine Health and Environmental Testing Laboratory, HETL) was completed upon sample delivery to the laboratory. Water chemistry parameters generally indicate the degree of pollution of a waterbody due to human activities. Heavy metals can be toxic to aquatic organisms above certain levels while an abundance of nutrients can lead to increased algal growth which in turn can cause a) oxygen depletion, and b) an increase in the abundance of macroinvertebrate grazers. Bacteria are not generally of concern for aquatic organisms; however, they can be a problem if they are of human origin and if a waterbody is classified as suitable for recreation in and on the water (as Capisic Brook is). It must be noted that in this study samples were analyzed simply for the presence of bacteria with no regard for their origin. Potential origins other than humans include wildlife (e.g., deer), birds (e.g., ducks), or pets, all of which can be found on or around Capisic Brook.

Habitat Assessments

1. The variability of the flow regime in the thalweg of the stream channel (the deepest, fastest-flowing part) was studied at both stations by measuring water velocity every 2 m along a 100-m long stretch of stream, starting at the rockbag location and proceeding upstream. These data were collected once in early September using a Global flow meter as detailed in App. vi. A variable flow regime is an important factor in habitat quality as it provides a wide range of environments for fish and invertebrates to occupy.

2. The abundance and size structure of woody debris was evaluated by measuring the mean diameter of all pieces of woody debris (branches, tree trunks) found inside the channel at both stations; this was done once in early September. Woody debris is important as it provides stable attachment sites for macroinvertebrates, provides and traps organic material for consumption by microbes and macroinvertebrates, allows the formation of pools for fish, and traps sediment.

3. A professional fluvial geomorphologist (a geologist specializing in the analysis of river systems) investigated Capisic Brook in the summer and fall of 2003 using a variety of field and computer analyses to determine the degree to which the natural morphology (structure) of the stream has been altered by urbanization. As mentioned in the introduction, urbanization may cause higher storm flows that can lead to problems with channel or bank erosion and subsequent sediment deposition; other potential effects of urbanization on stream morphology include channelization with a concurrent decrease in sinuosity (windyness) or entrenchment (containment of a stream within high banks so it cannot access a floodplain). The geomorphologic survey assessed whether these problems occur in Capisic Brook.

RESULTS AND DISCUSSION

Biological Monitoring

1. Macroinvertebrate samples collected from rockbags in August after an exposure period of four weeks in the stream have not yet been sorted to separate animals from debris (pieces of wood, leaves, grasses, sand, etc.). Observations during rockbag retrieval at the downstream station indicated a degraded community with the sample consisting mostly of the tolerant organisms amphipods, isopods, snails and some leeches. At the upstream station, samples contained a large amount of debris and sand and it was impossible to estimate community composition. Once sorted, the samples will be identified by a macroinvertebrate taxonomist, whose list of the exact numbers and types of organisms identified is expected in late winter/early spring of 2004. These samples will then be analyzed statistically by the MDEP to aid in determination of water quality conditions.

   The degraded macroinvertebrate community observed at the downstream station during rockbag retrieval is indicative of a stream that has poor water quality (low dissolved oxygen, high temperature, high nutrients; see following section), a reduced food supply from leaf and woody debris and inadequate habitat (see respective sections in

Habitat Assessments). It is likely that in 2003, as in previous years (see Previous Study), the downstream station on Capisic Brook will not meet the Class C aquatic life standards although this can only be confirmed when the biological data have been analyzed statistically. This result is not unexpected given that conditions in the watershed have not changed appreciably since the previous sampling event. Degraded macroinvertebrate communities similar to the one found in Capisic Brook also have been found in other urban streams sampled by the Biological Monitoring Program.

The data collected in this study (as presented in following sections as well as data not yet available) will be analyzed with the goal of identifying specific stressors that are responsible for the observed impairment in the macroinvertebrate community at the downstream station. At this point, it is not possible to say which particular stressor is causing the observed impairment, and the stressor identification process (see Introduction, MDEP Urban Streams Project) may indeed point to a whole suite of factors that need to be addressed to restore healthy aquatic communities in the lower section of Capisic Brook. Based on the data in hand, it is likely that high water temperatures, low dissolved oxygen levels, and high nutrient levels are potential stressors. Suggestions on how to deal with these stressors will be made in the respective sections below.

2. The fish assemblage found at the downstream station consisted of 12 American Eels (6-14" in length), 14 Mummichog (<1-2"), and 4 Nine-spine Sticklebacks (2.5"). Fish were not investigated at the upstream station.

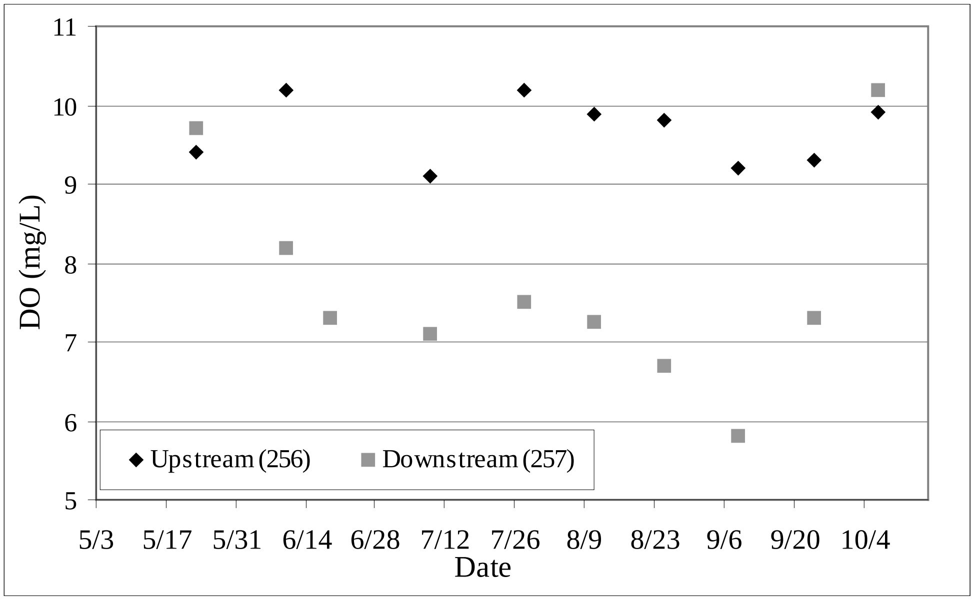
   The relatively low fish abundance and diversity at the downstream station is likely related to the poor water quality (e.g., low dissolved oxygen, high temperature) in this section. All species observed are known to have an intermediate to high level of tolerance to water pollution. Restocking Capisic Brook with native fish might be considered at a later point in time when the water quality has been restored, as the dam at the outflow of Capisic Pond presents a major barrier to fish movement, severely reducing the potential for natural recolonization. Advice on this issue should be requested from the MDEP's River section and the Maine Department of Inland Fish and Wildlife.

<u>Water Quality Monitoring</u>

1. Standard water quality parameters

   The concentrations of instantaneous dissolved oxygen (DO) at the upstream station on Capisic Brook were usually high, with a minimum of 9.1 mg/L in early July, and a maximum of 10.2 mg/L in early June and late July (black diamonds in Fig. 4). At the downstream station, DO concentrations were quite variable with a minimum of 5.8 mg/L in early September, and a maximum of at 10.2 mg/L in early October (gray squares in Fig. 4).

Fig. 4. Instantaneous dissolved oxygen in Capisic Brook



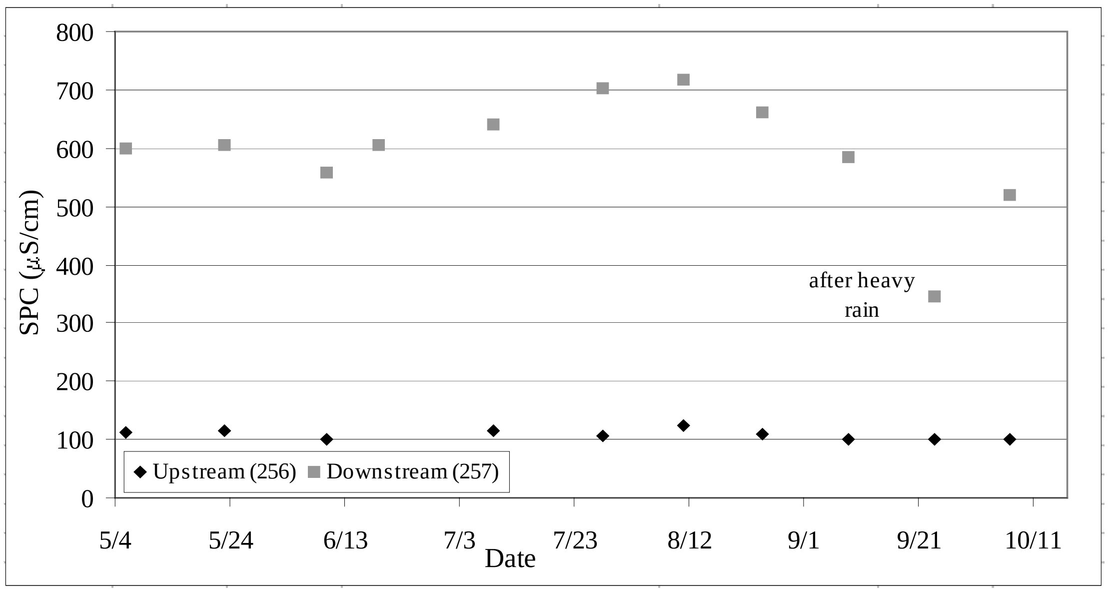
The dissolved oxygen concentrations in Capisic Brook at the upstream station always were at a level that favors healthy macroinvertebrate communities. This positive finding is likely attributable to two main factors: 1) the cool temperatures existing in this stretch of the stream (see below) allow the water to hold a high concentration of dissolved oxygen; and 2) the absence of algae means that oxygen levels are not depleted due to algal respiration and decomposition.

The dissolved oxygen concentrations in Capisic Brook at the downstream station were always above the Class C numeric criterion for summer DO levels (5 mg/L), and mostly above 7 mg/L, which is generally considered a healthy level for most macroinvertebrates.

Dissolved oxygen is required for respiration by all aquatic animals, but some organisms, such as trout or mayflies, require relatively high oxygen concentrations for healthy functioning. Insensitive organisms like leeches, midge larvae or some worms on the other hand can survive at low DO concentrations. In 2003, it seems that dissolved oxygen levels generally were high enough to support healthy aquatic communities at both stations on Capisic Brook, although concentrations at the lower station were less favorable than at the upstream station. Indeed, macroinvertebrate data from previous years showed that historically very few sensitive organisms were found at the downstream station, which may have been partly due to low DO concentrations (see Previous Study, above).

Instantaneous levels of specific conductance (also SPC or conductivity) at the upstream station were similar throughout the sampling season, with minimum and maximum values of 99 and 125 μS/cm, respectively (black diamonds in Fig. 5). At the downstream station, conductivity levels were more variable (in absolute terms), with minimum and maximum values during dry conditions of 520 and 716μS/cm, respectively (gray squares in Fig. 5). As noted on Figure 5, a value of 345 μS/cm was recorded after heavy rain (0.6”) the previous day, leading to a dilution of ions in the water and hence a lowering of the conductivity level.

Fig. 5. Specific conductance levels in Capisic Brook



The levels of conductivity in Capisic Brook at the upstream station are similar to those found by the Biological Monitoring Program in relatively undisturbed streams in Maine (unpublished data). This indicates that this stretch of the stream is not strongly affected by human activities. The water at the upstream station is mostly derived from springs in Evergreen Cemetery, with some contribution from a pond upstream of the sampling location. Information obtained from staff of the City of Portland Public Works Department (telephone conversation with Brad Roland on October 27, 2003) indicated that the subwatershed draining into this section of Capisic Brook receives only small amounts of stormwater runoff as most of the runoff in this area is currently directed into the city sewer system. It is likely that the minimal amount of stormwater runoff is an important factor in maintaining low conductivity levels at the upstream station.

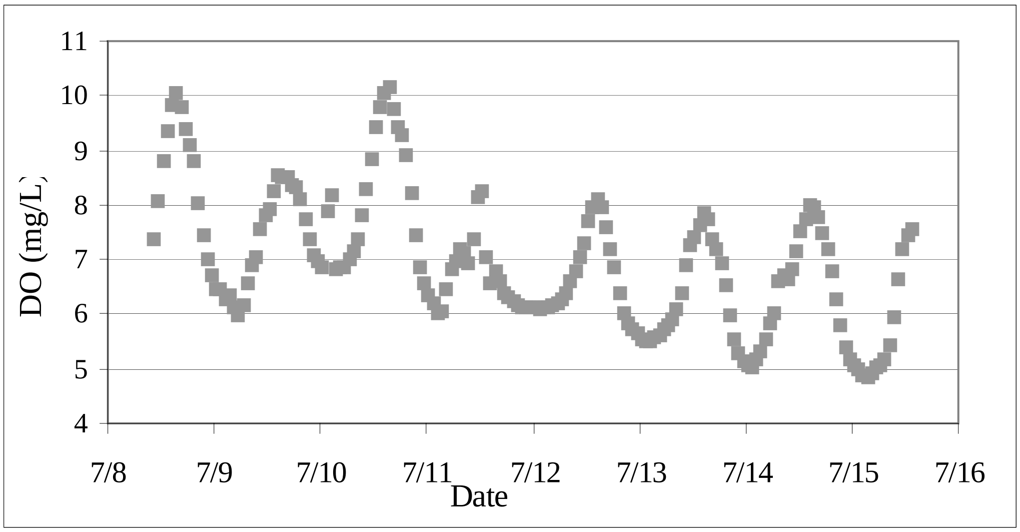
The levels of conductivity in Capisic Brook at the downstream station are similar to those found by the Biological Monitoring Program in other urban streams (unpublished data). These levels are much higher than those that would be encountered in minimally impacted streams in Maine, where conductivity is typically well below 100 µS/cm. While certain types of geological formations and certain soil types in a watershed can cause conductivity levels to be elevated naturally, it is likely that stormwater runoff from the extensive impervious surfaces near the downstream station contributes to a high conductivity level at this station. Data from previous sampling events show that the conductivity level has increased significantly over time, from a low of 195 µS/cm in 1996, to an intermediate value of 386 µS/cm in 1999 and a maximum of 716 µS/cm in 2003. This suggests that water quality has deteriorated over the past several years.

While it is not known how conductivity in and of itself may impact biological communities, it is known that heavy metals, which can cause high conductivity levels, can have negative effects on aquatic life (see 3. Water chemistry, Metals, below). In order to reduce conductivity levels at the downstream station in Capisic Brook, it would be important to reduce the quantity of stormwater runoff the stream receives, or to improve runoff quality for example by channeling it through a stormwater treatment system.

2. Continuous dissolved oxygen measurements

Continuous measurements of dissolved oxygen (DO) collected at the downstream station from July 8-15 indicated that DO concentrations showed strong diurnal fluctuations with high concentrations during the day and low concentrations at night (Fig. 6). Concentrations were close to 5 mg/L (the required minimum DO concentration for a Class C stream) on several occasions, and the diurnal range exceeded 2 mg/L every day during the measurement period (minimum range was 2.2 mg/L, maximum range 3.6 mg/L).

Fig. 6. Continuous dissolved oxygen at downstream station in Capisic Brook



Continuous dissolved oxygen (DO) data indicated that the DO concentration at the downstream station can come close to, or fall below, the required minimum concentration of 5 mg/L during the night. It should be noted that Class C criteria for aquatic life allow “some changes to aquatic life” to occur, and that they only require that “the structure and function of the resident biological community (is maintained)” (see Introduction, Rivers and Steams in Maine). A DO concentration of 5 mg/L does not normally favor healthy animal communities. Continuous data further showed that DO concentrations at the downstream station were below 7 mg/L, which is generally considered a healthy level, much of the time. These data suggest that DO concentrations at this station may have a negative effect on macroinvertebrate communities, i.e., a finding that is different from that reached based on instantaneous DO measurements (see above). Also noteworthy are the maximum DO concentrations measured, >10 mg/L in late afternoon, on two days. These concentrations in conjunction with the warm water temperatures shown in Fig. 8 suggest that the stream water may have been supersaturated with DO at times (i.e., there was more oxygen in the water than is normally possible under normal temperature and pressure), a typical sign of high algal productivity.

Factors that can influence DO levels are water temperature (as mentioned above, cold water can hold more DO than warm water), the abundance of algae (which both produce and consume oxygen, and require oxygen for decomposition by microorganisms), flow patterns (riffle sections of a stream help to re-aerate the water), and the presence of nutrients in the water (which can influence the abundance of algae). At the downstream station in Capisic Brook, all of these factors were found to impact DO concentrations. Water temperature during the summer months was quite high (see below, Fig. 8), leading to a reduction in the DO carrying capacity of stream water. Excessive algal growth was observed in July when the entire stream bed was covered by a thick mat of green filamentous algae (Fig. 7). An analysis of water flow patterns at this station (see below, Fig. 9) showed that the flow regime is homogeneous with a very low velocity, basically eliminating any possibility for re-aeration of the water. And chemical analysis (see below, Table 3) showed that nutrients (Total Nitrogen and Total Phosphorus) are above levels recommended by EPA for this region of Maine, contributing to excessive algal growth. These data and observations combined provide a good explanation for the observed pattern of DO concentrations at the downstream station. Suggestions as to reduce these problem factors are made below in the respective sections.

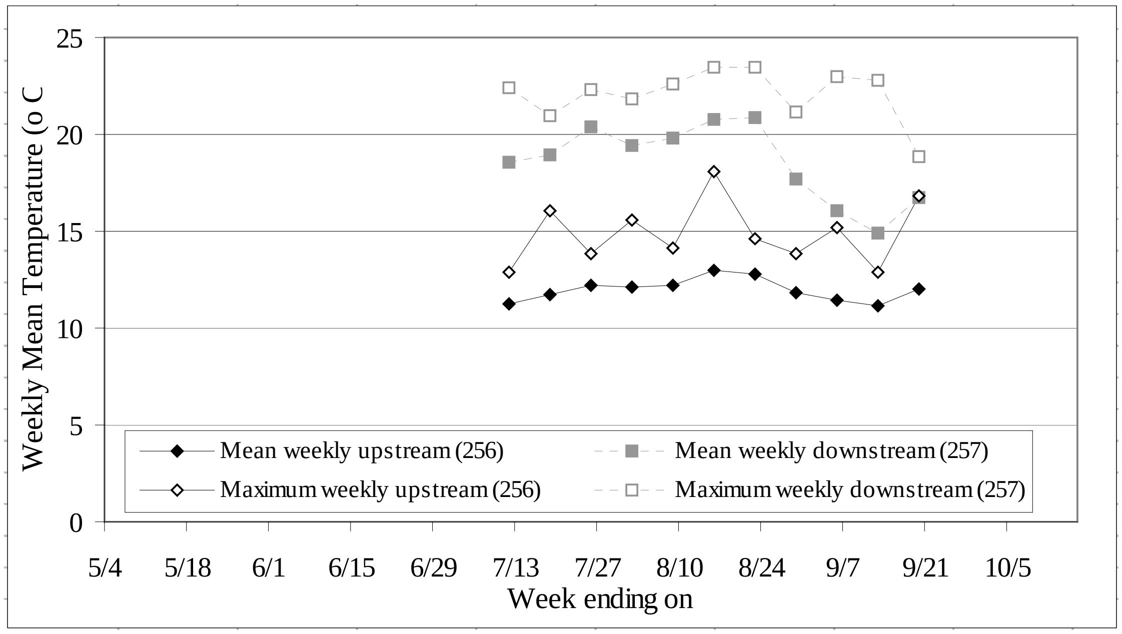
Fig. 7. Algae at downstream station in Capisic Brook on July 9, 2003

3. Water temperature

The temperature record at the upstream station (black diamonds and solid lines in Fig. 8) showed a relatively constant mean weekly temperature between 11 and 13º C throughout the recording period, but a highly variable maximum weekly temperature between13 and 18º C during that same period. Further data analysis showed that in all cases the high temperatures indicated by the maximum temperature records never lasted for more than 1.5 h with temperatures before and afterwards being lower by at least 2º C. At the downstream station (gray squares and dashed lines in Fig. 8), the mean weekly temperature was between 18 and 21º C from early July to mid-August before dropping to between 15 and 18º C for the remainder of the recording period. The maximum weekly temperature at this station fluctuated between 21 and 24º C between early July and early September before dropping to 19º C in mid-September.

The cool temperature regime generally encountered at the upstream station in Capisic Brook is very favorable for healthy animal communities. Factors responsible for this temperature regime are likely the closeness to the headwaters (springs in Evergreen Cemetery), an intact riparian zone with many large trees providing good shading, and an absence of heated stormwater runoff. It is important to preserve these conditions to ensure the continued favorable temperature conditions in this stretch of Capisic Brook.

Fig. 8. Continuous temperature in Capisic Brook



The relatively high mean and maximum temperatures recorded in midsummer at the downstream station in Capisic Brook were in, or close to, a range that is considered stressful for many fish and aquatic invertebrates. In late summer, the mean temperature dropped to a more favorable level although the maximum temperature still was above 20º C. Studies have shown that sensitive macroinvertebrates such as certain mayflies or stoneflies prefer temperatures below 17º C, while sensitive fish such as Brook Trout prefer temperatures below 20-22º C (see references in Varricchione 2002). Thus, as a prerequisite for restoring healthy biological communities, water temperatures at the downstream station in Capisic Brook must be lowered in summer.

High water temperatures are often associated with open stretches of stream, where the absence of vegetation in the riparian zone leaves the water fully exposed to solar heating. This is the case right around the downstream station in Capisic Brook, and also in some places upstream of the station. Also, heated runoff from impervious surfaces close to the stream probably significantly increases water temperatures. To lower water temperatures to a summertime level that promotes healthy biological communities in the stream, a priority should be to replant the riparian zone in as many places as possible, and particularly around the sampling location. Furthermore, stormwater runoff should be diverted away from the stream wherever possible.

3. Water chemistry

Water chemistry data are summarized in Table 3. The table shows the results from four sampling events at the upstream and downstream stations on Capisic Brook, and how the results compare with various types of numeric criteria for water quality. The CMC/CCC criteria (see Table 3) define acute (brief exposure) or chronic (indefinite exposure) levels above which certain compounds can have detrimental effects on aquatic organisms. Highlighted fields in the table indicate cases where the sampling results exceeded the numeric criteria, i.e., cases where negative effects may be expected to occur in aquatic organisms. Except for one sampling date on which bacteria levels exceeded chronic criteria, no problem results were found at the upstream station. At the downstream station, exceedances were found for two nutrients for which criteria exist (Total Nitrogen and Total Phosphorus), as well as for Chlorophyll *a* (one sample only), and bacteria (*E. coli*). Iron was the only metal analyzed that exceeded chronic or acute criteria although in some cases (Cadmium, Copper, Lead) the sensitivity of the analysis was insufficient to determine whether criteria were exceeded. Chloride values were well below water quality criteria.

Nutrients and bacteria. The surface water samples collected at the downstream station exceeded water quality criteria for Total Nitrogen (the sum of Total Kjeldahl Nitrogen, Nitrate-Nitrite-N, and Ammonia) and Total Phosphorus, Chlorophyll *a*, and bacteria (*E. coli*). Nutrient levels are often increased in urban streams as runoff from land includes material that is high in nitrogen and phosphorus, such as animal waste, fertilizers, or septic effluent. Furthermore, many cities, including Portland, operate a Combined Sewer Overflow (CSO) system which may allow raw sewage to enter a stream during storm events thus increasing the bacterial and nutrient load. The MDEP's Biological Monitoring Program has found that for a variety of reasons nutrient levels typically encountered in urban streams do not appear to have a major influence on macroinvertebrate communities (personal observation). These reasons include rapid uptake of nutrients by plants, flushing of nutrients out of the system by high flows, and the presence of other, more significant stressors. However, the excessive algal growth, highly fluctuating dissolved oxygen concentrations, and high nitrogen and phosphorus levels found at the downstream station suggest that nutrients can be considered significant stressors in Capisic Brook.

The relatively high Chlorophyll *a* values found at the downstream station (note that water quality criteria were exceeded only on one date) are likely related to high nutrient levels as the algal concentrations measured with this parameter respond favorably to nutrient input. High bacteria levels may be attributable to a variety of sources, from pets to wildlife to birds to CSOs and leaking sewer systems. The analysis performed in this study did not differentiate among these sources, but it is known that waterfowl use Capisic Brook as a resource and are a potential source of bacteria. Further sources of bacteria may be found in raw sewage or pet waste that enters the stream during storm events.

Because nutrients appear to be important stressors in Capisic Brook, it is imperative that various measures are initiated to control this stressor. Initial measures could include practices such as keeping pets away from the stream, picking up pet waste, ensuring that any septic systems in the watershed are in good working order, and that lawns in the vicinity of the stream are not fertilized. These practices also should reduce bacterial contamination. However, to effectively control nutrient, and bacterial, loads in Capisic Brook any entry of raw sewage into the stream must be prevented. To this end, the City of Portland is currently working on separating their CSO system thus eliminating this stressor in Capisic Brook. For complete nutrient control it may furthermore be necessary to reduce the amount of stormwater runoff the stream receives, or to improve its quality.

Table 3. Results from waters chemistry sampling on Capisic Brook

Parameters	Station (#)	Upstream (256)				Downstream (257)				Water Quality Criteria	
	Sample date	15-Jul	11-Aug	25-Aug	9-Sep	15-Jul	11-Aug	25-Aug	9-Sep		
	Unit										
Nutrients											
Total Kjeldahl Nitrogen	mg/L		~0.1	0.1		0.5	~0.5	0.4	0.4	NC	
Nitrate-Nitrite-N	mg/L		0.21	0.22		0.72	0.73	0.78	0.89	NC	
Ammonia	mg/L			0.01				0.05		NC	
Total Nitrogen	mg/L		0.21	0.33		1.22	0.73	1.23	1.29	0.71 [1]	
Ortho-phosphate	mg/L		0.004			0.015	0.019		0.016	NC	
Total Phosphorus	mg/L		0.015	0.015		0.077	0.063	0.046	0.050	0.031 [1]	
Dissolved Organic Carbon	mg/L		1.3	1.9			6.4	4.6		NC	
Total Organic Carbon	mg/L		1.3				6.6			NC	
Chlorophyll *a*	mg/L		~0.0005			~0.0042	~0.0032		~0.0028	0.00375 [1]	
Total Suspended Solids	mg/L		6	5		2	5	2	4	NC	
Bacteria (*E. coli*)	# col./100 ml	23	411		44	866	488		268	949 [2, 3]	142 [2, 3]
Metals										**CMC**[4]	**CCC**[4]
Cadmium	µg/L		ND 0.5			ND 0.5	ND 0.5		ND 0.5	0.64	0.32
Copper	µg/L		ND 5			ND 5	ND 5		ND 5	3.89	2.99
Iron	µg/L		210			1300	860		700	NC	1,000
Lead	µg/L		ND 3			3	ND 3		ND 3	10.52	0.41
Zinc	µg/L		ND 5			5	20		ND 5	29.9	27.1
Chromium	µg/L		1				1			16	11
Nickel	µg/L		ND 4				ND 4			363.4	40.4
Chloride	mg/L		20				157			860	230

Highlighted fields indicate problem parameters

NC, no criteria; ND, below stated detection limit of test.

[1] Criteria developed by EPA for Ecoregion XIV, which includes Capisic Brook.

[2] Criteria (instantaneous or geometric mean counts of the number of *E. coli* colonies) defined by Maine's Water Classification Program for Class C waters, which include Capisic Brook

[3] Results presented here are for bacteria of **any** origin while Maine Class B standards are for bacteria of **human** origin (see Introduction, Rivers and Streams in Maine). Note that in some studies where the origin of bacteria samples has been investigated, the majority of bacteria were **not** of human origin.

[4] CMC, Gold Book Instream Acute Criteria; CCC, Gold Book Instream Chronic Criteria. CMC and CCC, which were developed by EPA, denote the level of pollutants above which aquatic life may show negative effects following brief (acute) or indefinite (chronic) exposure.

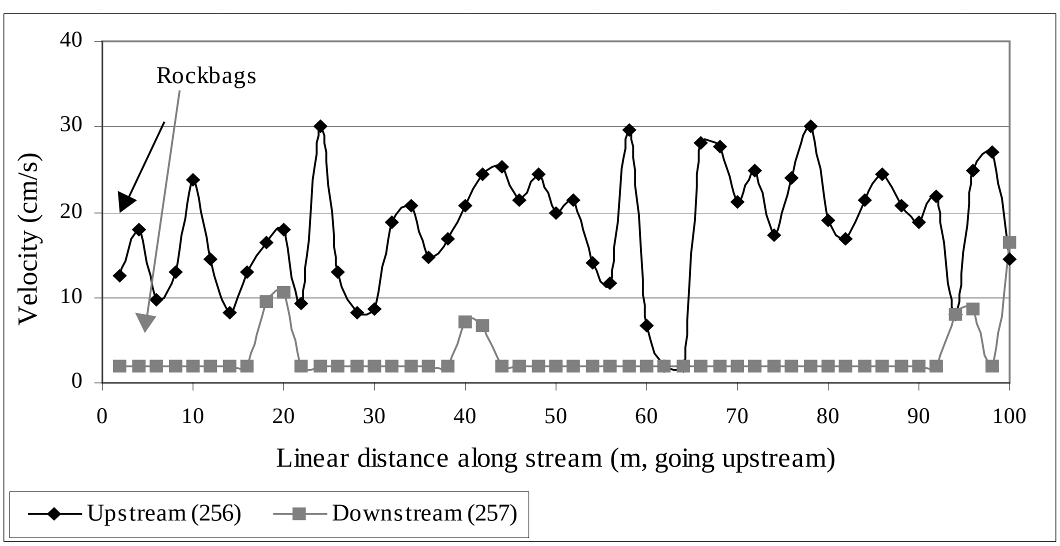
Metals. None of the seven heavy metals sampled in this study, or chloride, exceeded water quality criteria. Unfortunately, the detection limits for some metals (i.e., the lowest level of a component that can be reliably detected by a specific analytical procedure) were above the water quality criteria, for example in the case of copper for both chronic and acute criteria, and in the case of cadmium for chronic criteria. It should be noted that all metal data available at this point were collected during dry periods, with storm event data expected some time in January 2004. Varricchione (2002) studied a stream (Long Creek) in a highly developed area in South Portland, and detected high metal levels during storm events. Given Varricchione's findings, it is likely that Capisic Brook around the downstream station, which is also located in a highly developed area, suffers similar metal pollution problems. Beasley and Kneale (2002) cited as sources for heavy metal pollution in urban streams vehicles (tires, brakes, fuels and oils), pavement (concrete, asphalt), and surface debris (litter, winter road salts). Sediment entering the stream from construction sites, winter sanding activities, or soil erosion also may carry heavy metals and chloride. Negative effects of heavy metals on macroinvertebrates and fish have been confirmed in several studies, and include impacts such as declines in the rates of growth and reproduction, reduced population size, and changes in community structure (Paul and Meyer 2001, and Beasley and Kneale 2002, and references therein)

If storm event data confirm that (some) heavy metals in Capisic Brook exceed water quality criteria, it would be a further indication that road runoff needs to be diverted away from the stream, or treated before it enters the stream. Furthermore, sand left in parking lots and on roads after the end of the winter sanding season should be removed to reduce the chloride and sediment influx into the stream.

Habitat Assessments

1. The flow regime at the upstream station in Capisic Brook was highly variable, with velocities ranging from approximately 1 cm/s to 31 cm/s (Fig. 9). At the downstream station, very little flow was measured, with velocities ranging from non-detectable (graphed as ~1 cm/s) to ~11 cm/s.

Fig. 9. Variability of flow velocity in Capisic Brook



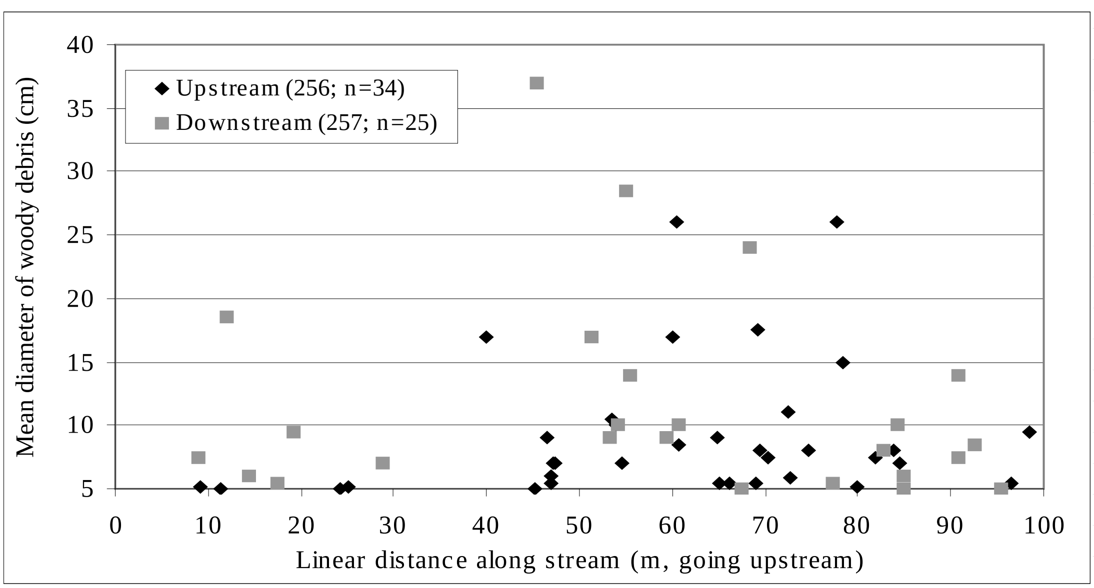
The variable flow regime found above the upstream station is another positive feature of this stretch of the stream as it provides aquatic organisms with a wide variety of environments to occupy, thus increasing the potential for a diverse biological community.

In contrast, the homogeneous flow regime found above the downstream station on Capisic Brook does not favor a diverse biological community because organisms requiring relatively swift flows, for example for feeding, will be absent in this environment. Furthermore, a slow flow regime promotes the accumulation of fine sediment on the stream bed which can smother organisms or make feeding structures such as the nets of some caddisflies ineffective. Finally, fast flowing areas in small streams are usually associated with miniature 'waterfalls' or riffles where the water tumbles over rocks, which contributes to a re-aeration of the water with dissolved oxygen. As shown above (Water quality monitoring, Continuous dissolved oxygen measurements), dissolved oxygen was identified as a likely factor impacting macroinvertebrate communities at the downstream station.

Restoring a variable flow regime in the lower section of Capisic Brook will require the expertise of a geologist specializing in the analysis of river systems (fluvial geomorphologist) as many factors affecting flow velocity and stream morphology will need to be considered. The benefits of variable flow to aquatic communities and overall stream quality would be many, though, and the restoration design for this section of Capisic Brook described below in the section on the geomorphologic survey results should be given serious consideration.

2. Woody debris in Capisic Brook above the upstream station was abundant (34 pieces) with a good size distribution (mean diameter of 5 to 38 cm; black diamonds in Fig. 10). Above the downstream station, fewer pieces were found (25) and the size distribution was more limited (5-29 cm; gray squares in Fig. 109).

Fig. 10. Distribution of woody debris in Capisic Brook



The abundance and size distribution of woody debris in Capisic Brook reflects the availability of wood in the riparian zone, the area adjacent to the stream. In Evergreen Cemetery above the sampling location, the riparian zone consists of many trees. Trees also are present in the riparian zone above the Lucas Street bridge (starting at ~40 m in Fig. 10), causing a relatively favorable abundance and size distribution of woody debris in this stretch of the stream. Immediately above the downstream station (from 0 to ~35 m in Fig. 10), however, the riparian zone is essentially bare of trees or other woody plants, with cattails and grasses accounting for the large majority of vegetation. The absence of trees and hence woody debris significantly reduces the habitat quality for aquatic organisms in this stretch of Capisic Brook in terms of habitat diversity and food supply.

Woody debris enhances the habitat quality for aquatic organisms by providing stable attachment sites, providing and trapping organic materials to be used as food sources, trapping sediments, and increasing habitat diversity. Trees in the riparian zone, besides providing woody debris, also represent a food supply in their own right once they have become woody debris and also by providing leaf input, especially in the fall, which is an important food source for a variety of macroinvertebrates. Because of the many advantages of a wooded riparian zone, it is advisable to plant trees beside Capisic Brook below the Lucas Street bridge, both to increase woody debris and food supply, and to provide more shading for the stream.

3. The fluvial geomorphologic survey of Capisic Brook concentrated largely on the "mainstem" from Evergreen Cemetery down to Capisic Pond; it did not include the branch going north/northeast across Warren Avenue and towards Forest Avenue, and only did minor assessments on the branch northwest towards Interstate 95 (Field 2003).

   Within the mainstem, the survey (Field 2003) found, among other things, that overall the stream is stable with few erosion problems; that it is largely free flowing (i.e., not channelized); and that there is a wide (>10 m) riparian buffer along the majority of stream length (Table 4). The survey also found, however, that there is only a narrow (1-10 m) riparian buffer along a significant length of stream, and slight entrenchment (i.e., vertical containment of the stream) along more than half of the stream (Field 2003); this entrenchment is either the result of direct human channelization or of much earlier/prehistoric downcutting of the channel through glacial deposits.

Table 4. Selected results from geomorphological survey of Capisic Brook

Feature		**Length (m)**	**Percent**
Bank stability	Major erosion	141	2.0
	Minor erosion	513	7.2
	Armoring	312	4.4
	Stable	6187	86.5
Channelization	Channelized	111	2.9
	Encroachment	593	15.7
	Unaltered channel	3084	81.4
Riparian Buffer Width	Absent (0 m)	1110	15.5
	Narrow (1-10 m)	1498	20.9
	Wide (>10 m)	4547	63.5
Entrenchment	Deeply entrenched	178	4.7
	Slightly entrenched	2040	53.8
	Not entrenched	1571	41.5

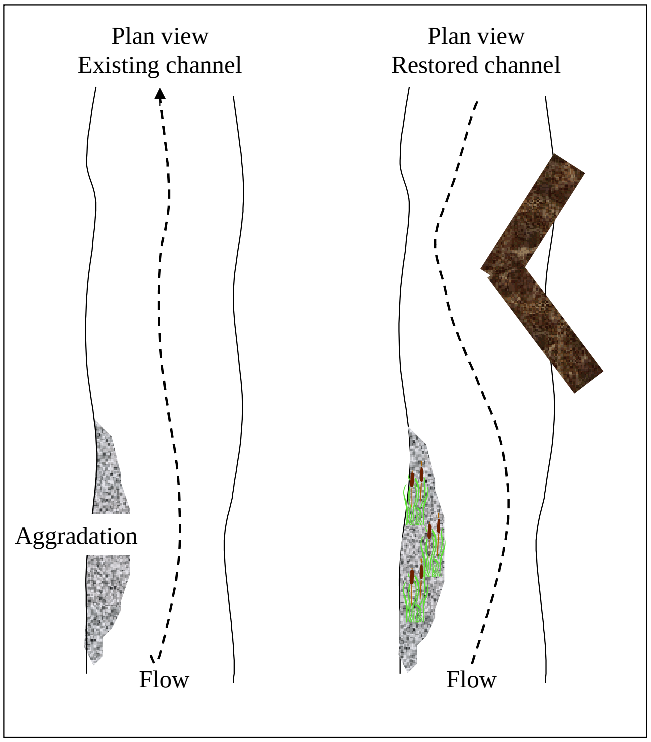
The survey (Field 2003) also included a Rapid Habitat Assessment which showed that most of Capisic Brook is near the lower end of the "Fair" ranking (ranking scale is Poor, Fair, Good, Reference). This indicates that stream habitat for biological communities is impaired in terms of physical attributes such as epifaunal substrate and available cover, sediment deposition, bank stability, or bank vegetative protection. This finding, in conjunction with the problems documented for the downstream station in terms of water quality (see Water Quality Monitoring, above), shows that the lower stretch of Capisic Brook does not favor healthy aquatic communities. It must be pointed out, however, that the upper section of Capisic Brook within Evergreen Cemetery also was rated as Poor although macroinvertebrate communities here have been found to be in good condition in recent years (see Previous Study, above).

A Rapid Geomorphic Assessment showed that most of Capisic Brook is near the high end of the Fair or the low end of the Good ranking (ranking scale is Poor, Fair, Good, Reference). This type of assessment is used to document current geomorphological adjustment processes occuring in a stream in response to various watershed, floodplain and channel modifications by evaluating channel degradation (incision or downcutting, i.e., lowering of stream bed elevation through erosion or scour of bed material), channel aggradation (i.e., raising of stream bed elevation through accumulation of sediment), channel widening, and changes in planform (i.e., the channel shape as seen from above). This assessment documented active incision near the upstream biomonitoring station. While incision is often caused by increased flow volumes resulting, for example, from urbanization, this particular instance of incision seems unrelated to development and may instead be natural, albeit unexpected for this location (Field 2003). The assessment furthermore documented aggradation in Capisic Brook above the downstream biomonitoring station, i.e., between Lucas Street and Brighton Avenue. This suggests that when this section of the stream was channelized, the channel was constructed too large for the dominant flows, and that subsequently the stream has been trying to reestablish an equilibrium by reducing channel width through the accumulation of sediment (Field 2003). While the majority of the accumulating sediment may be naturally derived from the underlying geology (see below), it is likely that some sediment enters the streams from roads, parking lots or construction sites.

The geomorphologic report includes one cautionary note based on the analysis of the surficial geology of Capisic Brook (Field 2003). Like other streams in this region, Capisic Brook lies within the Presumpscot Formation where the stream substrate consists of sand, silt and clay and only very little coarser material. Because of this dominance of fine sediments, any increase in the dominant discharge due to additional runoff, be it from increased impervious surfaces or greater diversion of runoff into the stream, could cause the erosion of accumulated sediment above the downstream biomonitoring station. This would lead to a reversion of the documented aggradation (see previous paragraph), and the formation of a newly enlarged channel able to convey the increased discharge (Field 2003). Furthermore, an increase in the dominant discharge also may cause erosion in other parts of Capisic Brook that have adjusted to the current flow patterns. Erosion, depending on extent and location, may endanger man-made structures such as bridges and buildings; it can also impair water quality for biological communities by increasing suspended sediment load and sediment deposition on the stream bed.

The geomorphologic report concludes with a suggestion for restoring the lower section of Capisic Brook (above the Lucas Street bridge), where channelization and aggradation were documented, to a more natural morphology, i.e., a narrower, more sinuous (windy) stream channel with a varied flow regime. This could be achieved by installing double wing deflectors in the stream, and vegetating the bars formed by accumulating sediment (see Fig. 11). Because this section of the stream was channelized many years ago (likely before 1964, Field 2003), the stream has had time to adjust to the alteration, and it is now approaching a new equilibrium condition. As a result, little future change should be expected, and a restoration project should be successful if not significant changes in the dominant peak discharge occur (Field 2003).

Fig. 11. Restoration design for downstream station on Capisic Brook (schematic representation, modified from Field 2003, Fig. 9a)



CONCLUSIONS

Results showed that at the upstream station in Capisic Brook water quality and most habitat indicators are in a good condition and favorable for healthy macroinvertebrate communities. Although 2003 macroinvertebrate data are not yet available for this station, all other results available to date suggest that this station will probably meet the aquatic life criteria for a Class C stream. In order to maintain this situation, it is important that runoff entering the stream from impervious surfaces upstream of this sampling station is kept to a minimum, and that a riparian zone with an intact forest is preserved.

At the downstream station in Capisic Brook, biological communities (macroinvertebrates and fish) were indicative of poor water and/or habitat quality. The diversity of animals present was low, and the majority of the species found are known to be tolerant to water pollution. An analysis of general water quality indicators (dissolved oxygen, conductivity, temperature) and chemical parameters (nutrients, bacteria, heavy metals) indicated that the lower section of Capisic Brook shows many of the effects typically encountered in urban areas, such as depressed dissolved oxygen concentrations, high water temperature, and elevated conductivity and nutrient levels. Habitat assessments also revealed evidence of typical urban stressors, such as an altered stream morphology, and riparian buffer width. It is expected that as yet outstanding analytical results will further underscore the overall poor condition of this section of Capisic Brook.

In two previous years (1996, 1999), the downstream station in Capisic Brook violated the aquatic life criteria for a Class C stream, and based on field observations it is expected that the same will be true in 2003. As a result, the Maine Department of Environmental Protection is required to develop a TMDL (Total Maximum Daily Load) plan for this stretch of the stream aimed at restoring aquatic communities to Class C standards. The data summarized in this report will form the basis for the TMDL plan to be developed in the winter and spring of 2004/2005. Other data not yet available, i.e., the macroinvertebrate identifications and water chemistry data from storm events, also will be utilized in the development of a TMDL plan. At this point, it is not yet clear which types of pollutants, or which allowable pollutant levels (loads), will be specified in the TMDL plan to improve Capisic Brook's macroinvertebrate community. Based on the information available to date, it seems likely that general recommendations such as those presented below will be taken into consideration in developing the TMDL plan for the downstream portion of the stream.

List of recommendations:

- Increase in the dissolved oxygen concentration in the stream
    - A reduction in water temperatures (see below) would likely improve the dissolved oxygen concentration as cool water can hold more oxygen than warm water.

    - A reduction in nutrient levels (see below) would likely improve the dissolved oxygen concentration by reducing algal growth and hence oxygen demand during respiration and decomposition.

- If stormwater treatment systems were installed to treat urban runoff before it enters the stream, they could be equipped with oxygenation units to increase the oxygen concentration in the discharged water.

- Reduction of the water temperature in the stream
    - Replanting of the riparian zone below the Lucas Street Bridge would provide shading that can aid in keeping water temperatures low.

    - A reduction in the temperature of road/parking lot runoff before it enters the stream may be achieved for example by channeling runoff through stormwater treatment systems.

- Reduction in the nutrient, bacteria and metal[1] levels in the stream
    - General Best Management Practices such as keeping pets away from the stream, picking up pet waste, ensuring that any septic systems in the watershed are in good working order, and that lawns in the vicinity of the streams are not fertilized would help reduce the nutrient and bacteria problems in Capisic Brook.

    - A separation of the City of Portland's combined sewer overflow (CSO) system will eliminate any input of raw sewage into the stream thus significantly reducing nutrient and bacterial loads.

    - A substantial reduction in the amount of storm runoff the stream receives may be required to eliminate most nutrient/metal problems. Alternatively, runoff quality may be improved for example by channeling if through a stormwater treatment system to remove solid particles to which many nutrients and metals adhere.

- Improvement in habitat quality in the stream and riparian zone
    - Replanting of the riparian zone below the Lucas Street Bridge would add valuable woody debris to the stream thus improving habitat quality and food supply for macroinvertebrates.

    - An improvement in channel morphology through stream restoration would markedly improve habitat quality for biological communities by reestablishing channel sinuosity and the habitats associated with it, and diversifying the flow regime.

    - A reduction of sedimentation problems could be achieved by ensuring that sand left on parking lots and roads after the end of the winter sanding

[1] During baseflow conditions, metals did not generally exceed water quality criteria but it is expected that a violation will be found during storm events.

season is removed, and that construction companies employ Best Management Practices aimed at containing sediment on site.

The list of recommendations given above only serves as a general example of the types of actions that could be taken near the downstream station on Capisic Brook to deal with some of the effects of urbanization on this waterbody. Detailed recommendations tailored to the specific stressors identified for this stretch of Capisic Brook will require the input of experts from fields such as biology, geology, and engineering.

Restoring healthy aquatic communities in Capisic Brook will require collaboration among several parties (regulatory agencies, the City of Portland, concerned citizens), as well as financial resources and time. The TMDL plan to be developed by the Maine Department of Environmental Protection will define allowable loads for particular pollutants such as sediment, and implementation of the plan should lead to a considerable improvement in stream health over the next few years. Future biological and water quality monitoring is advisable to determine whether the TMDL achieved its goal of restoring the resident aquatic communities to Class C standards at the downstream station in Capisic Brook, or whether additional actions are required.

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